SYSTEM CONCEPT
FOR THE
COMMUNICATIONS CONTROLLER AND
PROGRAMMABLE RF INFRASTRUCTURE
OF THE
AIRBORNE COMMUNICATIONS NODE (ACN)

September, 1997

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1. INTRODUCTION

The Defense Advanced Research Projects Agency (DARPA), working with the Defense Airborne Reconnaissance Office (DARO) is developing Unmanned Aerial Vehicles (UAVs) with differing missions, performance, and payload capabilities. One such UAV, the Global Hawk, is a High Altitude Endurance (HAE) vehicle that is initially being developed to carry Synthetic Aperture Radar (SAR) and visible and infrared (IR) imaging sensors for theater surveillance and target identification. DARPA is now developing an alternative payload for the Global Hawk that is to be devoted to enhancing warfighter communications during all phases of the conflict and communications for Operations Other Than War (OOTW). This modified Global Hawk and associated communications payload is called the Airborne Communications Node (ACN).

1.1 Scope

This document presents a set of functional objectives and goals for the ACN and defines a system concept and architectural framework based on the guidelines set forth in the Joint Technical Architecture (JTA). The information contained in this document describes expected and desired (i.e., goal) capabilities, services, interfaces, performance, and operation associated with the ACN. It is not intended to define or specify an ACN implementation.

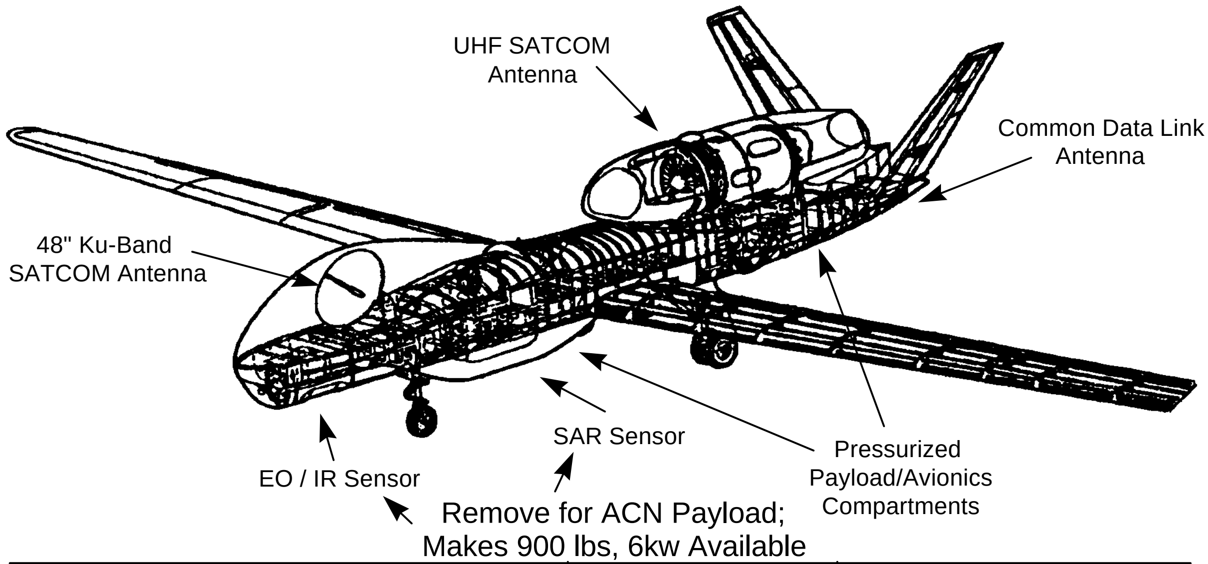
The expected capabilities described in this document are those attributes of the ACN design considered necessary to meet the overall program objectives. Goals are desired extensions to these capabilities that will enhance ACN operations.

1.2 Caveats

The following caveats should be considered in the ACN design and development.

1. Existing Global Hawk communications equipment and functionality is expected to remain in place. However, this does not preclude consideration of alternative designs in which the existing equipment is replaced or modified provided existing platform communications functionality is present.
2. The existing sensor payload on the Global Hawk will be removed for the ACN payload (see Figure 1). This will make available space, power, cooling, and weight for new communications equipment:

   - 900 lbs
   - 6 kW power
   - 4.5 kW cooling
   - 130 cu ft



Maximum Radius	3000 NM/24 Hr/3000 NM	Fuselage		Weights:	
Maximum Altitude	67,300 Ft	Width	4.8 Ft	Structure	3,920 Lbs
Loiter Time	42 Hrs	Length	44.4 Ft	Empty (incl fluids)	7,648 Lbs
Loiter Velocity	343 Kts	Wing		Payload	2,140 Lbs
Ferry Range	14,405 NM	Area	540 Sq Ft	Take-off-fuel	14,210 Lbs
Flight Critical Reliability	1 Loss in 200 (objective)	Span	116.2 Ft	Take-off-gross	24,000 Lbs
WB SATCOM	50 Mbps	Engine	AE3007H		

Figure 1 Global Hawk with Sensor Payload

3. There will be no stovepipe system design.
4. The ACN will be based on an open systems architecture without proprietary interfaces.
5. The ACN architecture will be a dynamic, reconfigurable/programmable architecture.
6. Antenna space will be limited. This will require minimizing the number of antennas available support the ACN.
7. The environment in which the ACN payload will operate is the same as that specified for the sensor payload.
8. The ACN design should support future growth and the addition of new capabilities (i.e., scaleable, modular approach).
9. Single-points-of-failure should be minimized
10. Innovative proposals for the ACN are encouraged.

1.3 References

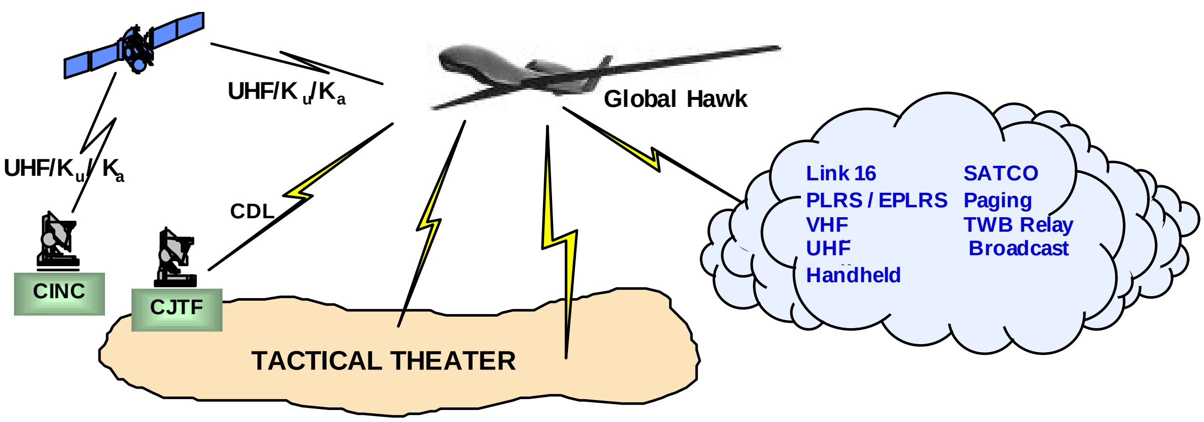
1. Joint Technical Architecture, Version 2.0, December 1997
2. Warfighter Internet Specification
3. Global Hawk Specification
4. ACN Handheld Study
5. ACN EMI Study
6. DARPA ACN Phase 0 Study, 1995
7. Common Data Link (CDL) Specification – Revision D
8. Programmable, Modular Communications System (PMCS) Guidance Document, Revision 2, July 1997

2. SYSTEM CONCEPT

The ACN system concept and functionality is described below. These were derived from a previous DARPA (Phase 0 Study, 1995) and from discussions with associated government agencies and services.

2.1 Operational Scenario

The ACN system concept is shown in Figure 2. This concept supports theater-wide communications as well as reach-back connectivity (e.g., connectivity to out-of-theater sites through direct satellite links). Proposed services include range extension, relay between users that are beyond line-of-sight (BLOS), gateway interconnection for dissimilar radios, theater paging, broadcast to forces on the move and a cellular-like handheld capability. Communication services span Very High Frequency (VHF), Ultra High Frequency (UHF), and Super High Frequency (SHF) bands with multiple simultaneous channels operating to accommodate the capacity needs of the user.



- **Global Hawk at 65,000 Ft. Altitude Provides Line-of-Sight Extension Up to 300+ Miles for Current and New Communications Systems**
  - **Connects Isolated and Rapidly Maneuvering Forces**
  - **Provides Reach-Back Connectivity to CONUS From Forward Elements**
  - **Provides Connectivity Among Dissimilar Radios Through ACN Gateways**
- **Self-Deployment Provides Communications Connectivity to Developing Theaters Worldwide Without Large In-Theater Assets**
  - **Eases Initial Air- and Sea-Lift Requirements**
  - **Consistent with Service Operational Concepts**

Figure 2 Airborne Communication Node System Concept

The 1995 DARPA Phase 0 Study established the operational utility of an ACN and described a trade-space for potential communications payloads for the Global Hawk UAV. The study also described the following desired services to the warfighter that an ACN might provide:

〈 BLOS Range Extension and Relay to:

- Overcome Terrain Blockage
- Support Rapid Maneuvers
- Overcome Limited Entry Logistics, Infrastructure Mobility

〈 Support New Operations Concepts
- Reachback Communications via ACN Satellite Relay
- Warfighter Internet
- Support for Forces On-the-Move & Early Entry without SATCOM Terminals

〈 New Classes of Service
- Tactical Broadcast Service (TBS) Augmentation for Forces On-the-Move (Omni-antenna)
- Theater Paging
- Handheld Radios/PCS services Using COTS Cellular/LEOSAT Technology

〈 Gateways between dissimilar radios and associated data/voice formats

The ACN is expected to operate with equipment currently fielded by the Services as well as provide new services. The ACN and associated ground segment is expected to be capable of reconfiguring and controlling payload elements, both prior to and during the mission.

2.2 ACN Expected Services

Table 1 provides the expected RF functionality and the numbers of RF channels to be supported by the ACN (This does not imply simultaneous operation of all the channels specified in Table 1). A half duplex (HDX) channel is defined as one modulated waveform within the frequency spectrum of interest providing either a transmit or receive capability. Either a FDX link or a FDX channel would typically require two HDX channels.

To provide flexibility to operate with a variety of deployed equipment and to adapt to changing operational needs, it is desirable to utilize multi-band, multi-function, programmable radios. Fortunately, the technology for such radios is becoming available through development efforts like DARPA's SPEAKeasy program and the Naval Research Laboratory (NRL) Joint Combat Intelligence Terminal (JCIT).

Table 1 ACN Programmable RF Services

Function	Purpose/Comments	Expected # of channels	Goal # of channels
Link 16	Air & Ground Situational Awareness	1 FDX	1 FDX
EPLRS	Position Reporting & Messaging	2 FDX	2 FDX
PLRS	Position Reporting	1 FDX	1 FDX
SINCGARS	HDX Combat Net Radios (voice & data)		
UHF SATCOM	Out-of-Theater Connectivity from ACN (Non-DAMA wideband 25KHz,	1 FDX	1 FDX
UHF LOS , Voice, Data and HaveQuick	Support UHF LOS communications	20 FDX	20 FDX
UHF Surrogate SATCOM	Support for TACSAT/DAMA users (MIL-STD-188-182, MIL-STD-188-183	2 Tx ECCM 4 Tx Single Carrier 6 ECCM Rx	20 HDX ECCM mode
Handheld Radio (HH) Pager Tx TBS	Cellular-Like Service May be integral part of HH downlink May be integral part of HH downlink	100 chnls FDX 1 Tx 1 Tx	200 chnls FDX 1 Tx 1 Tx
Wideband LOS link	Uplink GBS information to ACN for Broadcast to tactical users, High bandwidth trunk to ACN from In-Theater.	1 FDX	1 FDX
Ku SAT	Out of Theater Connectivity from ACN and TBS feeder link	1 FDX	1 FDX
High Capacity Trunk Radio (HCTR)/TWB	MSE Trunk Relay	3 FDX	3 FDX

2.2.1 BLOS Relay Services

The ACN is expected to include a relay function that will be used to provide connectivity between similar equipment using the same protocols and message formats. This function is essentially a retransmission of a received signal without a format change. ACN relay services should also support a frequency shifting capability since simultaneously receiving and transmitting on the same frequency would only be useful when the supported ground sites are beyond-line-of-sight of each other, when diplexers are incorporated, or when two directional (independently steered and non-interfering) antennas are used. The relay/bridging function will be used to provide range extension for both data and voice systems.

The ACN is expected to provide reachback connectivity for ground forces in theater via the Ku-band SATCOM link. This will require that the Ku-band SATCOM link provide a high speed (i.e., 1.544Mbps), full duplex capability.

The Mobile Subscriber Equipment (MSE) High Capacity Trunk Radio (HCTR), tactical wideband relay (TWB) in Table 1 should operate at 1.544Mbps or greater. This is a relay only; no "trunk drop" requirement is expected to be included as part of the ACN.

The Intelligence, Surveillance, and Reconnaissance (ISR) community desires a Common Data Link (CDL) relay be included as part of the ACN. An ISR sensor platform, when BLOS, would relay its CDL sensor data stream through an ACN relay to a ground station (via the CDL downlink). Such a CDL relay function normally requires either two CDL data link equipment suites or a CDL dual data link chassis. This goal should be addressed by working closely with the CDL and Airborne Information Transmission System (ABIT) programs. This goal is mentioned here for completeness and to address possible future ACN requirements.

2.2.2 Tactical Broadcast Services (TBS)

The Global Broadcast System (GBS) operates at 23 Mbps from non-mobile locations with fixed antenna pointing. The ACN is expected to augment GBS by providing a tactical broadcast service to terminals on-the-move with low gain, non-tracking antennas operating at 1.544Mbps. Figure 3 illustrates the ACN tactical broadcast scenario. All broadcasts require an uplink and downlink (broadcast) segment. The uplink segment must support both standoff and in-theater ground station placement, and be jam resistant. The broadcast segment must support aperture-disadvantaged users at significant ranges.

The broadcast information may come from a single injection site (e.g., the TBS Ground Segment) and/or conceivably from a distributed collection of sources multiplexed on-board the ACN. Information coming from the ground injection site can be either from the GBS or provided by the theater commander. The GBS information must be received by a GBS capable receiver and "filtered" so that only the appropriate information (up to 1.544 Mbps) is forwarded to the TBS injection point.

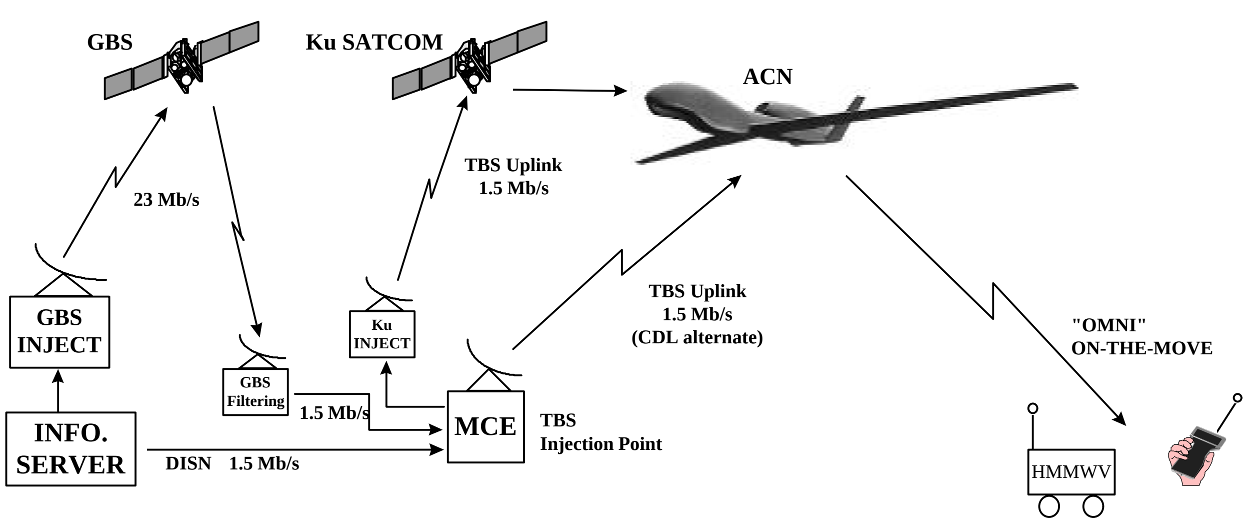


Figure 3 Tactical Broadcast Scenario

A possible candidate for the TBS injection point (or TBS ground segment) is the existing Global Hawk Monitor and Control Element (MCE). Modifications to the MCE to support the TBS would include the capability to accept a terrestrial TBS feeder data link (includes the extracted GBS information as well as other information from in-theater) and channel support to forward this data to the ACN via a SATCOM or Line-of-Sight (LOS) uplink. It is anticipated that this capability will require minimal additional processing from the MCE.

Possible TBS feeder link alternatives include modifying the existing Ku-band SATCOM link and/or LOS "CDL" uplink to support the tactical broadcast service. Three attractive factors favor the use of these alternatives: 1) the existing antenna systems will support the data rates anticipated for the TBS, 2) frequency allocation is already arranged, and 3) ACN doppler correction has already been implemented.

The baseline Global Hawk Ku-band satellite link is a low rate downlink (nominal 200 Kbps into the aircraft) and a high rate uplink (nominal 45 Mbps from the aircraft) using a Ku-band commercial satellite. This asymmetry is opposite from that desired for a broadcast feed. The ACN receive capability must be expanded to support the broadcast injection. Changes to leased commercial satellite transponder uplink or downlink data rates must be coordinated closely with DISA. The transponder lease may need to be renegotiated, and impact to the transponder lease funding profile must be explored.

The CDL data link could be modified to provide a full duplex, high data rate (i.e., at least 1.544 Mbps) LOS uplink to the ACN. The baseline CDL link is a low rate uplink (200Kbps into the aircraft) coupled with a high rate (10.71, 137, 274 Mbps) downlink. This asymmetry is also opposite from that desired for the TBS. CDL can provide full duplex, high data rate services to the ACN. The baseline CDL includes a family of Command Link "uplink" data rates and a family of Return Link "downlink" data rates. The Command Link data rates include 200 Kbps, 2 Mbps, and 10.71 Mbps. The Return Link data rate include 10.71, 137, and 274 Mbps. The particular CDL implementation could be negotiated with the DARO.

In addition, full duplex, high bandwidth SATCOM and LOS data links will be required to support future ACN requirements (i.e., Warfighter Internet, reachback capability to CONUS). It would be desirable to modify the CDL and Ku-band SATCOM links to support symmetrical full duplex service providing support for the TBS feeder link as well as for future ACN requirements.

2.2.3 Handheld Services

The ACN Handheld Communications Services, technical objectives and goals are described in Handheld Services Study. The interfaces to the ACN Communications Controller (CC) will include signaling, voice and data. The Handheld (HH) module will support up to 200 simultaneous calls (voice and/or data). Most of the 200 HH calls are expected to be handled within the HH module. However, the CC is expected to support the switching of both voice and data connections to other ACN assets**.** This switching may be to another similar handheld system or to dissimilar voice and data functions associated with the ACN (i.e., voice to other PBX type systems through ACN, Internet Protocol (IP) data to routing function).

An early estimate of the HH unit traffic relayed through the ACN is 50 % of 200 calls. However, a worst case scenario is 200 users requiring data relay through the ACN. Assuming a worst case data loading scenario, at 64 Kbps per user/call, the Communications Controller infrastructure will need to support a sustained data rate of approximately 12.8 Mbps (6.4 Mbps for 100 users). This assumes that there is sufficient data capacity out of the ACN to support data relay to/from the Handheld module. In addition, this does not account for message acquisition delay times, buffering times, and encryption/decryption processing times which will increase the sustained data rate requirement.

2.2.4 Warfighter Internet Services

The specific ACN requirements for the Warfighter Internet are TBD at this time. However, the Warfighter Internet is expected to require crosslinks to other airborne nodes, IP routing, and additional network management and control functionality. The HH system is expected to be an integral part of the Warfighter Internet. The Communications Controller will need to support the extra data throughput from the crosslinks and ground users (some of this throughput has already been addressed in considering the IP data traffic coming from the HH module). The Warfighter Internet is expected to add an additional 1.544 Mbps to 4.5 Mbps (i.e., two crosslinks and one in-theater T1 link) additional data throughput requirement to the inter-networking function of the Communications Controller.

2.2.5 Internal Connectivity, Routing/Switching Services

The primary purpose of the ACN is to enhance the connectivity to, from, and among forward elements and elements on-the-move. It is desirable for the ACN to provide interoperability between as many of its communications services as possible and practical. This will require gateway services between dissimilar radios. This includes: signaling and format conversions, protocol translations, routing and switching services, etc.

2.2.5.1 Gateway Services

The ACN is expected to provide a gateway functionality that supports information flow between two dissimilar radios (i.e., different waveforms, crypto configurations, TRANSEC) and/or signaling formats. This function can vary from RF, IF, or baseband switching, to digital message reformatting needed to accommodate differing transmission protocols and standards (including encryption and decryption). The gateway function is expected to support both data and voice networks. The ACN is expected to perform waveform and message translation between U.S. systems. Future ACN capability growth may incorporate gateway services between U.S. and Allied systems. Table 2 shows a goal connectivity matrix.

Table 2 ACN Connectivity

	Link 16	EPLRS	PLRS	SINCGARS	UHF Radio	HH Services	Ku SATCOM	UHF SATCOM	MSE Relay(HCTR)	BDCST Tx
Link 16	R	G	G	NA	NA	NA	NA	NA	NA	NA
EPLRS	G	R	G	NA	NA	NA	NA	NA	NA	NA
PLRS	G	G	R	NA	NA	NA	NA	NA	NA	NA
SINCGARS	NA	NA	NA	R	G	G	G	G	NA	NA
UHF Radio	NA	NA	NA	G	R	G	G	G	NA	NA
HH Services	NA	NA	NA	G	G	R	G	G	NA	NA
Ku SATCOM	NA	NA	NA	G	G	G	NA	NA	NA	G
CDL LOS	NA	NA	NA	G	G	G	G	NA	NA	G
UHF SATCOM	NA	NA	NA	G	G	G	NA	NA	NA	NA
MSE Relay (HCTR)	NA	NA	NA	NA	NA	NA	NA	NA	R	NA

G =Gateway R = Relay NA = Not Applicable HH = Handheld

2.2.5.2 Voice Services

The ACN is expected to support switching of voice services between all transmit and receive entities as appropriate and practical. The switching and translation of voice services may require implementing multiple encoding/decoding (CODEC) algorithms on-board the ACN. The minimum expected capability is voice interoperability between VHF and UHF systems. The goal is to support voice service interoperability between all applicable ACN circuits.

Support for the propagation (through the ACN) and translation of the internal signaling from the Handheld module will be required to support switching of voice and data channels within the ACN. This is to include any applicable address translations, signaling and management service conversions, etc.

2.2.5.3 Data Services

The ACN is expected to include a routing function that will enable an ACN to appear as a network node in a larger theater-wide network structure. This capability will provide data communications support for terminals/workstations using the Department of Defense (DoD) standard suite of TCP/IP protocols. Migration to IP V6 is a goal.

2.2.6 Multiple ACN Environment

A goal for the future ACN environment is to function either as a standalone communications platform or as part of a multiple platform airborne network. When more than one ACN platform is deployed to support the same theater of operations, the platforms will be expected to transfer data between each other through the use of a crosslink. This capability will also provide additional range extension capabilities. The ACN architecture should not preclude the addition of this functionality.

2.3 ACN Monitoring And Control

The ACN Communications Controller function is expected to monitor and control all communications equipment associated with the ACN payload. Initially, the ACN configuration would be pre-established on the ground, supporting a pre-planned set of user requirements for the ACN mission. However, as the service demands change during the mission, the ACN configuration may change.

The control scenario (see Figure 4) for the ACN communications payload will be similar to control of the sensor payload on the Global Hawk. Vehicle flight control is handled by the MCE, which can be within line of sight of the UAV and operate through the LOS CDL or operate beyond line of sight over either the Ku-band or the UHF satellite link.

Monitoring and controlling the communications payload may be from in-theater elements or from a monitor and control element out of theater. The design should incorporate redundant links for ACN monitoring and control and support both LOS and reachback modes of operation. Security for the ACN monitoring and control links should be at the system high level (i.e., the level of an ACN "Red" backplane).

2.3.1 Ground Segment

Two options for supporting the ACN monitor and control ground segment are:

1. Modification of existing equipment to incorporate the ACN monitoring and control, and
2. Development of a separate, standalone capability.

Modifying the Global Hawk MCE to include a capability to monitor and control the ACN payload is the preferred solution. Changes to the existing MCE should be minimized. Existing Global Hawk command and control functionality and interoperability must be maintained. The command and control for the ACN communications payload should be able to take advantage of processing, memory, and communications resources formerly used by the sensor payload, which will not be implemented in the ACN.

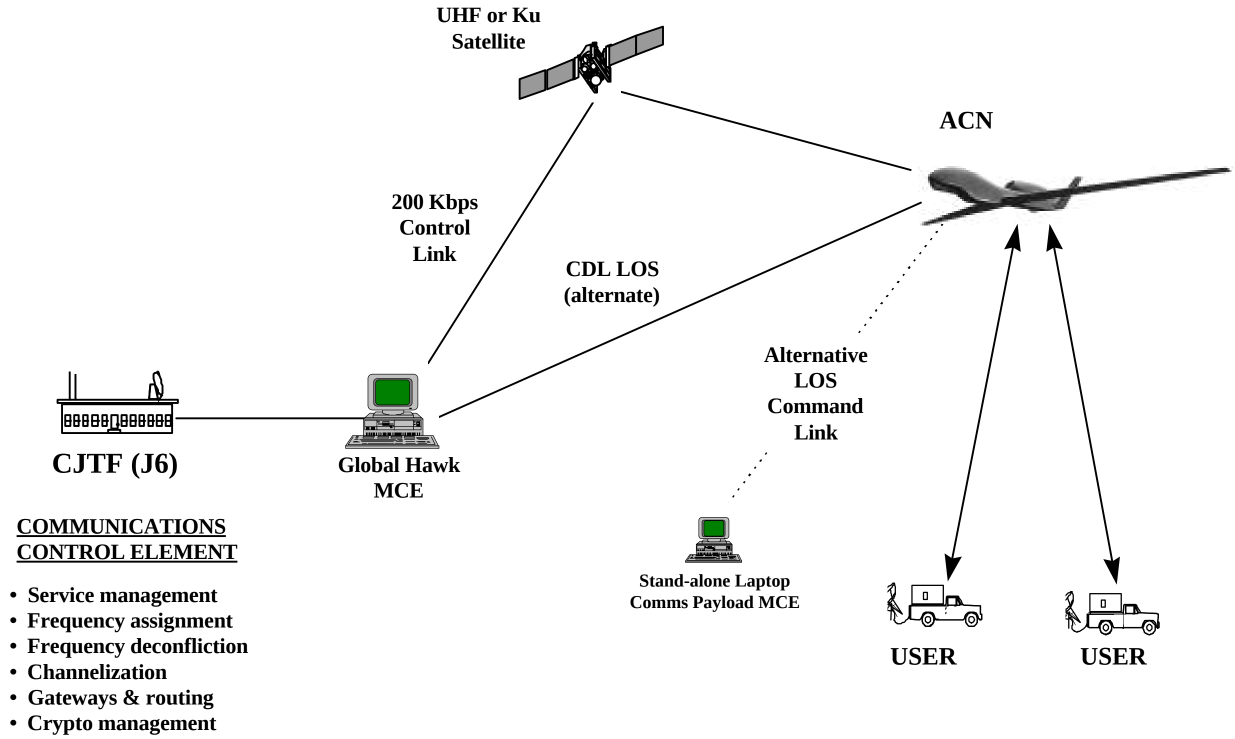


Figure 4 ACN Monitoring and Control Concept

A standalone "laptop" ACN monitoring and control station with dedicated control link is also a desired option to allow warfighter control within the theater-of-operations (i.e., not collocated with the Global Hawk MCE). Separate, dedicated, assured communications with the ACN would be required. The MCE would be expected to maintain control of the ACN payload and provide for the handoff to a secondary controller. This concept is also illustrated in Figure 4.

There are three options for a Command Link, as indicated in Figure 4. The three Command Links could be the CDL, UHF or Ku-band SATCOM, or the alternative LOS Command Link from the MCE. All three Command Link options currently available could provide 200 Kbps to support the ACN payload monitoring and control function. Higher data rates exist within the CDL family of Command Link data rates, for potential future use. These existing command links support the platform command and control as well as the sensor payload monitoring and control. The existing command link is partitioned as follows:

〈 170 Kbps for Primary Mission Equipment Commands (PMEC)
〈 20 Kbps for audio
〈 5 Kbps for Executive Function Command (EFC) - used for platform data link control
〈 5 Kbps for Sync.

PMEC are data sent via the command link from the Prime Mission Equipment (PME) operators at the user facility through the link to equipment on the platform. The 170 Kbps command link channel is programmable for up to ten individual PME users. Data rates in each of the ten combined channels are programmable in 5 Kbps increments. The ACN monitoring and control link capacity is expected to be less than or equal to the command link capacity required for the current sensor payload.

2.3.2 Control Functions

The communications payload control is expected to be managed at the Theater Command level although inputs to this function may come from lower echelons. Typically, the theater addresses issues such as frequency management/assignment and cryptographic functions must be addressed. These functions apply to both ACN and non-ACN communications systems.

Flight control of the Global Hawk UAV is accomplished in three phases: Launch and Recovery, En-route, and Mission Control. Launch and recovery is the responsibility of the Global Hawk Launch and Recovery Element (LRE). This may be far removed from the in-theater mission operating area. Flight control at the LRE is typically accomplished with a dedicated UHF LOS link. The LRE then transitions to a UHF SATCOM Link for en-route flight control. The inherent delay associated with a SATCOM link is acceptable for en-route control via waypoints where it would not be acceptable for “hands-on” maneuvering control associated with take-off and landing. The LRE performs the following functions:

〈 Mission plan delivery to the UAV
〈 Departure and approach path modification
〈 Path displays
〈 Local UAV control
〈 UAV preflight checkout
〈 Control handoff to and from the MCE

The MCE provides overall planning and control of mission and en route flight operations. The MCE provides planning, sensor processing, and ground communications interfaces for the UAV. At any time during the mission, the MCE is capable of exercising control over the aircraft except when the LRE is controlling takeoff and landing. The MCE interface requirements encompass the following:

〈 Land line and UHF SATCOM to the LRE for mission plan download
〈 UHF SATCOM to and from the UAV
〈 CDL and Ku-band SATCOM for processing sensor data from the UAV
〈 CDL and Ku-band SATCOM for command and control.

At some point, UAV flight control transitions from the LRE to the MCE. There are two options for this transition. It can either be done in the en-route phase, in which case the MCE must include a UHF SATCOM capability, or it can be done in the final operating area via a UHF LOS capability provided the MCE is within the footprint of the UAV. If the operational mission requires direct “hands on,” real-time, flight control of the UAV then a dedicated UHF LOS link is required at the MCE. There may be situations where the UAV operating area can extend beyond LOS from the MCE and flight control would have to revert to waypoints and assigned loiter areas conveyed via a UHF satellite link. In any event, it is essential to have redundant flight control capabilities at the MCE, which include both LOS and a satellite capability.

The ACN payload command and control is partitioned into the following functional modules:

〈 On-board Monitor and Control

- Executes commands from the ACN MCE
- Processes configuration information from the ground segment
- Provide status information to the ground segment

〈 ACN Monitor and Control Element Ground Segment

- Payload/network configuration and planning
- Planning tools for mission planning and configuration
- Generates configuration files for upload to the ACN
- Tech Control Element
- Upload of Configuration files
- Man-in-the-loop interface
- Near real-time control of the ACN
- Payload monitoring and status
- Security management

The initial loading of the ACN payload configuration data is expected to take place on the ground via terrestrial communications (i.e., Local Area Network (LAN)). While on station, the ACN payload will receive commands and provide status via the command and control data link.

2.4 Security Requirements

The ACN is expected to provide cryptographic support to allow simultaneous secure operations between all connections defined for relay and gateway services support. The ACN is expected to handle traffic at levels of unclassified through Top SECRET/Sensitive Compartmented Information (TS/SCI). A Multi-level Security (MLS) requirement is not anticipated. However, simultaneous, multiple levels of security can be supported by employing multiple levels of encryption at the user level.

2.5 Technical Issues

2.5.1 Technical Challenges

One of the most difficult technical challenges is resolving the Electromagnetic Compatibility (EMC) issues associated with many radios on one platform. This is typically accomplished through a combination of efforts, including careful frequency management, antenna placements, interference cancellation, and control of spurious emissions from transmitters and spurious responses in receivers.

Multi-band, multi-function, programmable radios are expected to be used to provide the flexibility to operate with a variety of deployed equipment and to adapt to changing operational needs. A significant challenge will be to provide this desired set of programmable RF services and to provide the interconnection services within the size, weight, and power constraints of the ACN. There is also significant challenge in realizing a communications controller onboard the ACN that can coordinate the operating modes of the payload with all other communications in the tactical theater as well as providing the message routing and translation capability necessary to realize the required Gateways.

Security management presents another important technical challenge. Control of encryption devices and keys (with over-the-air rekeying) is needed. The issues associated with gateways between systems protected by encryption must also be solved (bring down to baseband unencrypted and re-encrypt)

2.5.2 Specific Technical Issues

2.5.2.1 Link 16 to EPLRS (and VMF) Interoperability Issues

Seamless exchange of real-time ground, air, and surface situation awareness information and command and control (C2) information for coordination of joint mission engagements is a requirement short-fall identified in every CINC's Integrated Priority List, and is a priority issue identified by the Joint Battle Center as needing a solution. Due to the existence of multiple data formats, multiple/dissimilar data link networks, with dissimilar connectivity and performance characteristics, seamless exchange of information cannot always be effected in the timelines required for these time-critical missions, without reverting to voice connections.

Link 16 uses UHF (near 1 GHz); VMF systems use VHF. The differences in frequency ranges are incompatible. UHF is very much line-of-sight and preferred by air elements, although it is susceptible to attenuation by vegetation, etc. VHF is slightly beyond-line-of-sight and can provide ground forces with some ability to penetrate foliage, vegetation, etc. Due to the differences in frequency ranges, consequent data rate limitations arise due to Shannon's Limit and the Nyquist Limit.

The J-Series Family of TADILs includes TADIL J, VMF, and F-Series messages. Many of the data elements for these message format families are common to all three. Many of the mapping and navigation algorithms for this family of TADILS are common to all three. Link 16 uses fixed-format TADIL J messages which are 70 bits in length. VMF uses variable-format messages which vary in length. TADIL J messages flow at higher data rates and are often stored within 80-bit COTS registers for parsing and manipulation. The 70-bit message format provides an elegant solution with 80-bit registers. VMF messages flow at lower data rates and may be parsed and manipulated in real-time by COTS computers. VMF formats are well-suited to real-time parsing and manipulation. Although there are some interoperability issues, DISA and the JCS/J-6 continue to pursue interoperability.

For seamless exchange of real-time ground, air, and surface situation awareness information and command and control (C2) information between Link 16 and Variable Message Format (VMF) (and/or EPLRS), the following differences in the two standards must be handled by an intermediate device (i.e., message translator/forwarder, gateway):

(It is important to note that the interoperability issues between Link16 systems and VMF systems and/or Link 16 systems and EPLRS are similar).

<u>Identification</u> - The first step to data forwarding is the need to implement a scheme within the message translator/forwarder so that Link 16 and EPLRS/VMF messages can be identified and differentiated.
<u>Addressing</u> - Link 16 and VMF (and/or EPLRS) have unique and incompatible addressing schemes. The message translator/forwarder function must include an equivalent addressing resolution "protocol" to provide the mapping between the two different forms of addresses.
<u>Metering</u> - There is a significant difference in data rates between Link 16 and EPLRS/VMF systems, and further, given the Time Division Multiple Access (TDMA) structure of Link 16, messages can be

delivered with a predetermined speed of service (SOS) requirement. Due to the different data rates, the message translator/forwarder function must include the ability to perform message metering.
Receipt Compliance Rules - For certain message types, the Link 16 system message protocol is embedded within the radio function, and the radio provides the acknowledgment procedure independent of the host system. The same applies for a Network Control Station (NCS-E) based community for User Command Message (UCMs) and Data Output (DO) messages which are acknowledged at the radio level. In both systems, a message that has not received an acknowledgement (within specified time) is retransmitted automatically. The message translator/forwarder function must therefore have the ability to recognize these types of messages and provide a pseudo-acknowledgement on behalf of the remote participants.
Time Stamping/Data Age - The message translator/forwarder function must include 'embedded' processing to correlate and disseminate bi-directional data in an efficient manner. In that regard, the ability to register bi-directional Time of Day (TOD) arrival times is essential since forwarding rules should be a function of data age and pertinence.
Link 16 Ground Assets - One item, though it may sound trivial, is to mention the current JTIDS Army Terminal deployment plan. Army JTIDS assets are currently considered 'theatre' assets, and are used mainly in Theatre Air Defense (THAAD, Patriot). Although FAAD units use JTIDS, the lower level shooters are equipped only with EPLRS RSs. For a EPLRS/Link 16 gateway application, current doctrine and JTIDS deployment plans have to be changed to have JTIDS assets available to support the data transfer.

2.5.2.2 SINCGARS Interference

VHF SINCGARS radio performance is significantly degraded by interference in ECCM mode; both theater and cosite.

Cosite interference effects are highly dependent on transmit/receive isolation. A single active transmit cosite interference source, a transmit-to-receive isolation of 30 dB, and a required raw bit error rate of 10^{-2}, requires a received signal power of -67 dBm (WP 930000226). However, with antenna isolation of 45 dB, the receive signal power required is reduced to -90 dBm. The 30 dB isolation case results in an ACN coverage range reduction from the desired 200 miles to approximately 100 miles (see Table 3). More than one active transmitter on the aircraft reduces performance further. The limited isolation available between ACN VHF transmit and receive suggests no more than two active ECCM transmitters can exist on the ACN without unacceptable performance degradation unless interference cancellation mechanisms are implemented

In, addition, theater interference results from the ACN being within LOS of all SINCGARS radios within the theater. Each radio in ECCM mode acts to interfere with the desired signal. The number of hop channels is 2320 and 100 users would result in a collision approximately 0.05 percent of the time. This alone can result in unacceptable error rates. This problem may be solvable with directional antennas and/or by spectrum management. If possible, VHF antennas should be separated by at least one wavelength, roughly 6 meters, to avoid placing one antenna within the near field of another.

Proposals to implement these services should include performance analysis of SINCGARS radios in the following operational scenarios:

〈 All ACN nets in ECCM mode,

〈 All ACN nets in single frequency mode, and

〈 The ACN receives in ECCM mode but transmits single frequency.

The analysis should also be extended to address Have Quick ECCM mode radios as well.

Table 3 SINCGARS Link Calculations

100 Mile Radius			200 Mile Radius		
Frequency	50.000	MHz	Frequency	50.000	MHz
Wavelength	**5.9958**	**meters**	Wavelength	**5.9958**	**meters**
Range	161.25	kilometers	Range	320.62	kilometers
	100.21	**miles**		**199.27**	**miles**
	87.07	**nautical miles**		**173.12**	**nautical miles**
Data Rate (Kbps)	**16.00**		Data Rate (Kbps)	**16.00**	
TRANSMIT			**TRANSMIT**		
PA Power	50.00	Watts	PA Power	50.00	Watts
	16.99	**dBW**		**16.99**	**dBW**
Component & Line Losses	3.00	dB	Component & Line Losses	3.00	dB
Antenna Gain (Peak)	0.00	dBi	Antenna Gain (Peak)	0.00	dBi
Pointing Loss	0.00	dB	Pointing Loss	0.00	dB
Radome Loss	0.00	dB	Radome Loss	0.00	dB
Available U/L EIRP	**13.99**	**dBW**	Available U/L EIRP	**13.99**	**dBW**
PROPAGATION			**PROPAGATION**		
Free Space Loss	**110.58**	**dB**	Free Space Loss	**116.55**	**dB**
Atmospheric Loss	0.00	dB	Atmospheric Loss	0.00	dB
Polarization Loss	0.00	dB	Polarization Loss	0.00	dB
Total Propagation Loss	**110.58**	**dB**	Total Propagation Loss	**116.55**	**dB**
RECEIVE			**RECEIVE**		
Received Power Density	**-101.18**	**dBW/m2**	Received Power Density	**-107.15**	**dBW/m2**
Received Power (Omni)	**-96.59**	**dBW**	Received Power (Omni)	**-102.56**	**dBW**
Receiver Noise Figure	**4.00**	**dB**	Receiver Noise Figure	**4.00**	**dB**
Noise Temperature	**728.45**	**K**	Noise Temperature	**728.45**	**K**
Receive Gain	**0.00**	**dB**	Receive Gain	**0.00**	**dB**
Receiver G/T	**-28.62**	dB/K	**Receiver G/T**	**-28.62**	dB/K
Noise Bandwidth	42.04	dB-Hz	Noise Bandwidth	42.04	dB-Hz
	16.0000	**kHz**		**16.0000**	**kHz**
E_b/N_0	**61.35**	**dB**	E_b/N_0	**55.38**	**dB**
Received Power	**-66.59**	**dBm**	**Received Power**	**-72.56**	**dBm**
Received Power Density	-108.63	dBm/Hz	Received Power Density	-114.60	dBm/Hz

2.5.2.3 Impact of ACN UHF Surrogate Satellite Mode on UHF DAMA Terminals

One of the functions of the ACN is envisioned to be a UHF "surrogate" satellite. The intention is to allow UHF DAMA capable radios to use the ACN as a relay between and among nets in the theatre being serviced by the ACN. The following paragraphs examine system-wide impacts and the impacts of this concept on the Network Control Station (NCS) and existing terminals such as the AN/PSC-5 Spitfire.

2.5.2.3.1 System Level Issues

At present the frequencies allocated for UHF SATCOM are listed in MIL-STD-188-181. There are two UHF satellites in each of four footprints around the earth. Each UHF follow on (UFO) will have 21 5-kHz channels and 17 25-kHz channels. These will be divided into pools of dedicated channels, those that are in DAMA mode and those for Demand Assigned Single Access (DASA) use. If the ACN surrogate uses the same set of frequencies, there will be areas of interference with UHF SATCOM users. That is, there will be areas being serviced by the ACN where UHF SATCOM use is not allowed and/or there will be areas using UHF SATCOM which precludes use of the ACN in UHF SATCOM surrogate role. More analysis is required to determine the actual geometries in which problems arise. The system management issues of tracking network and terminal locations vs. SATCOM or surrogate satellite use may make this approach unreasonable.

A way to avoid this problem is to use a different (as yet unallocated) set of frequencies that are offset from the current set of UHF SATCOM frequencies. At present, however, the NCS and Spitfire only allow a user to select one of the allocated UHF SATCOM channels. Terminals (including the NCS) would need to change the software for Human Machine Interface (HMI) to allow an operator to select a new surrogate channel, define new HMI to radio control code to accept the new commands, and define new radio control code. The terminals and NCS would also need to have a new database of channel numbers and up/down frequencies in order to properly use any of the orderwires related to channel switching for either 5 or 25 kHz operation. This may create an even larger regulatory problem because the use of these frequencies is negotiated internationally.

One assumption is that the ACN surrogate DAMA satellite capability is only used where the UHF SATCOM services are not available (due to jamming, etc.). In this case, the DAMA SATCOM frequencies can be used without interference. However, it must be noted that the ACN will also be providing new communications services (e.g., Warfighter Internet and Handheld type services) that provide capabilities that may obviate the need for DAMA SATCOM. Since supporting UHF DAMA SATCOM on the ACN would very likely require modifying existing ground terminals and NCSs, there will be trade-offs (e.g., cost, operational, doctrinal, technical, etc.) that deserve more analysis before a definitive decision is made.

2.5.2.3.2 NCS Issues

In this section, we assume the above system level issue has been dealt with and that terminals and the surrogate NCS, herein called SNCS, are able to communicate on a mutually agreed set of frequencies. Currently the Air Force has fielded a NCS that can control up to eight UHF channels (hardware limitation). The software allows control of up to 64 channels of 5-kHz DAMA and will be upgraded to also provide control of 25-kHz channels. The NCS software, however, makes certain assumption based on its use over geostationary satellites, which would need to be changed. While not stated explicitly, we assume the use of a transportable ground-based SNCS, although the concept of an ACN-based SNCS needs to be examined.

1. Doppler due to ACN motion
MIL-STD-188-182 requires the NCS to have its frequency within 100 Hz of the nominal (commanded) frequency. If the NCS is near the edge of coverage area for the ACN, it may have a Doppler shift of up to 180 Hz, thus violating the intent of the standard. The NCS doesn't do Doppler correction for its uplink. (The NCS modems estimate Doppler on the downlink and use it as part of its signal acquisition/demodulation loop. However, that information is not fed back to adjust the uplink). This would need to be changed for a SNCS.

2. NCS scheduling constraint
In order to accommodate half duplex terminals like the Spitfire, the NCS scheduler is somewhat constrained in what slots can be assigned. It allows sufficient time between transmit and receive slot assignments to account for the transmit/receive time offset due to long propagation to the UHF satellite. While the current scheduler would function properly for ACN relay, eliminating this restriction could make overall channel efficiency better. This should be addressed further for ACN surrogate use.

3. NCS burst rate assignment
For 5-kHz DAMA, the terminal sends the NCS it received downlink signal to noise (SNR) ratio at time of login. This value is used by the NCS to determine what symbol burst rate should be used when the terminal communicates. MIL-STD-188-182 specifies the burst rate as a function of SNR. However, when the ACN is used in surrogate satellite mode, variations in SNR due to path dynamics could potentially cause a problem. The current NCS software that adheres to MIL-STD-188-182 may not properly assign burst rates. If the ACN were only going to fly short patterns, limiting the SNR variations, the solution would be to adjust the burst rate table in MIL-STD-188-182 by an appropriate amount. However, if the ACN needs to fly longer patterns, the only viable solution may be assigning the lowest burst rates possible to all users, thus making inefficient use of the channel.

For 25-kHz DAMA, there is a "link test" function, but how the NCS uses it is unspecified. Here the problem may be more dramatic since the NCS cannot simply command new lower burst rates at will. Frame formats for 25-kHz DAMA use specify allowed burst rates and how many of each type there are. Within a given format, it may not be possible to communicate due to the SNR variation. This is obviously a terminal issue in addition to an NCS issue.

2.5.2.3.3 Terminal Issues

1. Ranging for half duplex terminals

According to current standards, all terminals must range to the satellite before logging in or requesting service. Terminals listen to their range burst, calculate round trip delay time, and offset their receive and transmit times by this amount. Range bursts are 280 msec for 5-kHz and 75 msec for 25-kHz. These are both significantly longer than the round trip delay time to an ACN. Thus, a half duplex terminal like the Spitfire, simply cannot range to an ACN and could not even request services as currently implemented. There is a workaround for 5-kHz DAMA, however.

The maximum range to an ACN at 65,000 feet corresponds to a one-way delay of about 1.7 msec. Since guard times are at least 25 msec for any burst type in 5-kHz DAMA, by setting the terminals transmit time at or just slightly ahead of the receive time would allow a terminal to operate without jamming other users. This would require changes to the modem functions to NOT range and to set the transmit time in another fashion. The GUI would also need to be changes to allow an operator to select either UHF SATCOM or surrogate mode. For 25-kHz DAMA, the required time accuracy of 0.875 microsec precludes the above approach, and we have not yet determined an alternative.

In summary, as currently implemented, half duplex terminals such as Spitfire, could not operate over an ACN due to self-jamming of range bursts. Inability to properly range precludes any other use of a Spitfire. Software changes would allow a Spitfire to operate on 5-kHz DAMA, but we have not determined a workaround for 25-kHz DAMA.

2. New UHF frequencies

As discussed above, it may be necessary to define new UHF frequencies to be used for ACN surrogate service. At present, the Spitfire only allows an operator to use one of the existing frequencies. Software would need to be added for the “surrogate mode” allowing a different set of frequencies in the HMI and radio control modules as well as database changes and interface definitions. The use of frequencies that have not been internationally negotiated is an issue that needs investigation.

3. Potential Doppler problem

For two terminals communicating over a surrogate ACN, their signals may encounter a Doppler shift of up to 350 Hz. A certified terminal like the Spitfire is only required to be within 400 Hz of the commanded frequency to meet MIL-STD-188-182. These factors could add to cause up to a 750 Hz Doppler shift per burst. It is unknown whether Spitfires can operate under these conditions.

4. Variation in SNR

As mentioned above, if the ACN is in a small racetrack pattern, even a stationary terminal will experience a 3 dB variation in SNR. For 5-kHz DAMA, the SNR is reported at login time and the NCS uses it to assign the highest burst rate that still supports adequate communications. If a high value is reported at login because the ACN is close, and high burst rates are assigned, communications will break down as the ACN moves away. Currently, a Spitfire starts calculating SNR as soon as it starts receiving Forward Orderwire (FOWs) from a NCS. If an operator immediately tries to login, the SNR may represent only one or two samples, potentially leading to the above problem. If the terminal logs in later, it reports a time-averaged SNR with similar problems. A work around would be to have the terminal be required to calculate SNR over the time period of an ACN flight path and report the lowest SNR, thus assuring of adequate communications. This would, of course, require terminal operators to know what that time period is, and have a way to input this information. So changes would need to be made to HMI and the Spitfire software involved with calculating and reporting SNR. If flight paths are too long, a better alternative may be to force the SNCS to just assign the most robust slots it can

5. Potential memory limitations

At present, the Spitfire stores three modules of software on an EPROM - for MIL-STD-188-181, 182, and 183. Depending on what the terminal is doing, one and only one module is downloaded to RAM for use at a time. If the Spitfire is required to also have surrogate modes of these three standards, it is necessary to determine how much additional memory is needed and whether there is room to house it.

2.5.2.4 Ku-band Satellite

The existing Ku-band satellite communications suite is designed to support 50 Mbps return data rate to a Mission Control Ground Station with an 11.3 meter antenna and a forward data rate of 200 Kbps. A 6 meter antenna is proposed to support initial testing. The ACN expects to use the existing Ku-band suite of equipment for high data rate services and needs to be able to support symmetrical data for at least 2 T1 trunks (~ 3 Mbps). A link budget, assuming a commercial transponder on the SBS-6 satellite, indicates that symmetrical data rates up to 10 Mbps are possible using approximately 25% of one transponder. Tables 4 and 5 show the forward and return link budgets for the existing Ku-band satellite terminals.

Table 4 Link Budget Calculations (ACN to MCE 6m)

UPLINK			**DOWNLINK**		
Frequency	14.200	GHz	Frequency	11.700	GHz
Wavelength	**0.0211**	**meters**	Wavelength	**0.0256**	**meters**
Range	40571.92	kilometers	Range	**40571.92**	**kilometers**
	25215.61	**miles**		**25215.61**	**miles**
	21907.08	**nautical miles**		**21907.08**	**nautical miles**
Data Rate (Kbps)	**10000.00**		Data Rate (Kbps)	**10000.00**	
U/L TRANSMIT			**OPERATING POINT**		
PA Power	400.00	Watts	Satellite SFD	-82.00	dBW/m2
	26.02	**dBW**	Input Back Off (IBO)	**17.26**	**dB**
Component & Line Losses	1.50	dB	OBO (from sat data)	20.26	dB
Antenna Gain (Peak)	42.00	dBi	Maximum Satellite EIRP	46.50	dBW
	1.14	**meters (.55 IF)**	Available D/L EIRP	**26.24**	**dBW**
	44.95	**inches (.55 IF)**	Percent sat power	***0.94%***	
Pointing Loss	0.50	dB	**D/L PROPAGATION**		
Radome Loss	1.00	dB	Free Space Loss	**205.98**	**dB**
Available U/L EIRP	**65.02**	**dBW**	Atmospheric Loss	0.60	dB
			Polarization Loss	0.50	dB
U/L PROPAGATION			Total Propagation Loss	**207.08**	**dB**
Free Space Loss	**207.66**	**dB**			
Atmospheric Loss	0.60	dB	**D/L RECEIVE TERMINAL**		
Polarization Loss	0.50	dB	Power at Ground Terminal	**-180.84**	**dBW**
Total Propagation Loss	**208.76**	**dB**	Ground Term Antenna Gain	55.00	dBi
				5.10	**meters (.55 IF)**
U/L RECEIVE				**16.73**	**feet (.55 IF)**
Received Power Density	**-99.26**	**dBW/m2**	Ground Term Noise Temp	202.00	K
Received Power (Omni)	**-143.74**	**dBW**	Ground Terminal G/T	31.95	dB/K
Satellite G/T	3.73	dB/K	Ground Term Pointing Loss	0.50	dB
Noise Bandwidth	70.00	dB-Hz	Downlink E_b/N_0	**9.21**	**dB**
	10.00	**MHz**	Independent D/L Margin	**3.71**	**dB**
Uplink E_b/N_0	**18.59**	**dB**			
Independent U/L Margin	**13.09**	**dB**	**SUMMARY**		
			Total Available E_b/N_0	**8.74**	**dB**
			Required E_b/N_0	5.50	dB
			C/N for Implement Losses	0.00	dB
			Net Signal Margin	**3.24**	**dB**

Table 5 Link Budget Calculations (MCE 5m to ACN)

UPLINK		
Frequency	14.200	GHz
Wavelength	**0.0211**	**meters**
Range	40571.92	kilometers
	25215.61	**miles**
	21907.08	**nautical miles**
Data Rate (Kbps)	**10000.00**	
U/L TRANSMIT		
PA Power	400.00	Watts
	26.02	**dBW**
Component & Line Losses	1.00	dB
Antenna Gain (Peak)	55.00	dBi
	5.10	**meters (.55 IF)**
	200.77	**inches (.55 IF)**
Pointing Loss	0.50	dB
Radome Loss	1.00	dB
Available U/L EIRP	**78.52**	**dBW**
U/L PROPAGATION		
Free Space Loss	**207.66**	**dB**
Atmospheric Loss	0.60	dB
Polarization Loss	0.50	dB
Total Propagation Loss	**208.76**	**dB**
U/L RECEIVE		
Received Power Density	**-85.76**	**dBW/m2**
Received Power (Omni)	**-130.24**	**dBW**
Satellite G/T	3.73	dB/K
Noise Bandwidth	70.00	dB-Hz
	10.00	**MHz**
Uplink E_b/N_0	**32.09**	**dB**
Independent U/L Margin	**26.59**	**dB**

DOWNLINK		
Frequency	11.700	GHz
Wavelength	**0.0256**	**meters**
Range	**40571.92**	**kilometers**
	25215.61	**miles**
	21907.08	**nautical miles**
Data Rate (Kbps)	**10000.00**	
OPERATING POINT		
Satellite SFD	-82.00	dBW/m2
Input Back Off (IBO)	**3.76**	**dB**
OBO (from sat data)	6.76	dB
Maximum Satellite EIRP	46.50	dBW
Available D/L EIRP	**39.74**	**dBW**
Percent sat power	***21.09%***	
D/L PROPAGATION		
Free Space Loss	**205.98**	**dB**
Atmospheric Loss	0.60	dB
Polarization Loss	0.50	dB
Total Propagation Loss	**207.08**	**dB**
D/L RECEIVE TERMINAL		
Power at Ground Terminal	**-167.34**	**dBW**
Ground Term Antenna Gain	41.60	dBi
	1.09	**meters (.55 IF)**
	3.58	**feet (.55 IF)**
Ground Term Noise Temp	202.00	K
Ground Terminal G/T	18.55	dB/K
Ground Term Pointing Loss	0.50	dB
Downlink E_b/N_0	**9.31**	**dB**
Independent D/L Margin	**3.81**	**dB**
SUMMARY		
Total Available E_b/N_0	**9.29**	**dB**
Required E_b/N_0	5.50	dB
C/N for Implement Losses	0.00	dB
Net Signal Margin	**3.79**	**dB**

2.5.2.5 CDL Communications Analysis

CDL provides a family of data rates for the Command Link, including 200 Kbps, 2 Mbps and 10.71 Mbps. The Global Hawk currently uses the 200 Kbps Command Link standard, spread over a 97 MHz bandwidth. The Global Hawk uses the CDL Return Link data rate standards, with up to 274 Mbps available for sensor data at X-band.

The return link's RF infrastructure is sized to provide data at rates much higher than expected to be needed by the ACN and therefore, should support any downlink function within the 8° beam width of the X-band antenna required by the ACN. The forward link has sufficient RF infrastructure capacity to support data rates much greater than 10 Mbps. A sample link budget is shown in Table 6. Because the 200 Kbps command channel is spread across 97 MHz, a 10 Mbps forward link, using 10 MHz spectrum, will result in little degradation to either when occupying the same frequency spectrum.

A potential use for the "CDL data link" is to provide high speed, full duplex connectivity to the in-theater assets. This assumes that the mission control link is located at or near a connection point of the theater communications infrastructure. A separate ground station must be within approximately 2 miles of the mission control equipment to receive the return link. Another potential use for this capability is to provide a "feeder link" for the Tactical Broadcast Services.

Table 6 Sample Link Budget for the CDL Forward and Return Links

CDL Forward Link			CDL Return Link		
Frequency	9.800	GHz	Frequency	10.300	GHz
Wavelength	**0.0306**	**meters**	Wavelength	**0.0291**	**meters**
Range	320.62	kilometers	Range	320.62	kilometers
	199.27	**miles**		**199.27**	**miles**
	173.12	**nautical miles**		**173.12**	**nautical miles**
Data Rate (Kbps)	**10000**		Data Rate (Kbps)	**274000**	
TRANSMIT			**TRANSMIT**		
PA Power	40.00	Watts	PA Power	70.00	Watts
	16.02	**dBW**		**18.45**	**dBW**
Component & Line Losses	0.50	dB	Component & Line Losses	0.50	dB
Antenna Gain (Peak)	41.00	dBi	Antenna Gain (Peak)	22.20	dBi
	1.47	**meters (.55 IF)**		**0.16**	**meters (.55 IF)**
	58.04	**inches (.55 IF)**		**6.34**	**inches (.55 IF)**
Pointing Loss	0.50	dB	Pointing Loss	0.00	dB
Radome Loss	0.00	dB	Radome Loss	0.80	dB
Available U/L EIRP	**56.02**	**dBW**	Available U/L EIRP	**39.35**	**dBW**
PROPAGATION			**PROPAGATION**		
Free Space Loss	**162.39**	**dB**	Free Space Loss	**162.82**	**dB**
Atmospheric Loss	0.60	dB	Atmospheric Loss	0.60	dB
Polarization Loss	0.50	dB	Polarization Loss	0.50	dB
Total Propagation Loss	**163.49**	**dB**	Total Propagation Loss	**163.92**	**dB**
RECEIVE			**RECEIVE**		
Received Power Density	**-66.21**	**dBW/m2**	Received Power Density	**-82.88**	**dBW/m2**
Received Power (Omni)	**-107.47**	**dBW**	Received Power (Omni)	**-124.57**	**dBW**
ACN Antenna Gain	22.50	dBi	Antenna Gain	35.80	dBi
ACN Noise Temperature	2304.00	K	Noise Temperature	331.00	K
ACN G/T	**-11.12**	**dB/K**	**Ground Station G/T**	**10.60**	**dB/K**
Noise Bandwidth	70.00	dB-Hz	Noise Bandwidth	84.38	dB-Hz
	10.00	**MHz**		**274.00**	**MHz**
Eb/No	**40.00**	**dB**	Eb/No	**30.25**	**dB**

2.5.2.6 High Capacity Trunk Radio (HCTR)

The HCTR is being developed and built to provide Asynchronous Transfer Mode (ATM) trunking from 1.544 Mbps to 45 Mbps for the Army’s Battlefield Information Transmission System (BITS) Architecture. These radios are expected to provide mobile and static gateway services. The frequencies are expected to be at X-band and used in both LOS and airborne relay links. The relay is expected to be configured as bent-pipes. One airborne relay is currently being built. Because of the wide beam width of the ACN to ground link, there is a potential to interfere with the ground LOS relays. Careful spectrum management is essential.

A notional concept is to have 25 Watt amplifiers with 3 dB hemispherical antennas on the ACN relay and 4 foot antennas on the ground. Antennas have also been considered with beam shapes to provide more Effective Isotropic Radiated Power (EIRP) toward the horizon. Table 7 shows a sample link budget associated with this configuration using a 200 nautical mile slant range. The receiver noise temperatures assumed are the same as the CDL X-band link.

Table 7 Sample HCTR Link Budget

HCTR To ACN			ACN to HCTR		
Frequency	8.400	GHz	Frequency	7.300	GHz
Wavelength	**0.0357**	**meters**	Wavelength	**0.0411**	**meters**
Range	320.62	kilometers	Range	320.62	kilometers
	199.27	**miles**		**199.27**	**miles**
	173.12	**nautical miles**		**173.12**	**nautical miles**
Data Rate (kbps)	**45000**		Data Rate (kbps)	**45000**	
TRANSMIT			**TRANSMIT**		
PA Power	25.00	Watts	PA Power	25.00	Watts
	13.98	**dBW**		**13.98**	**dBW**
Component & Line Losses	0.50	dB	Component & Line Losses	0.50	dB
Antenna Gain (Peak)	39.50	dBi	Antenna Gain (Peak)	3.00	dBi
	1.45	**meters (.55 IF)**		**0.02**	**meters (.55 IF)**
	56.98	**inches (.55 IF)**		**0.98**	**inches (.55 IF)**
Pointing Loss	0.00	dB	Pointing Loss	0.00	dB
Radome Loss	0.00	dB	Radome Loss	0.80	dB
Available U/L EIRP	**52.98**	**dBW**	Available U/L EIRP	**15.68**	**dBW**
PROPAGATION			**PROPAGATION**		
Free Space Loss	**161.05**	**dB**	Free Space Loss	**159.83**	**dB**
Atmospheric Loss	0.60	dB	Atmospheric Loss	0.60	dB
Polarization Loss	0.50	dB	Polarization Loss	0.50	dB
Total Propagation Loss	**162.15**	**dB**	Total Propagation Loss	**160.93**	**dB**
RECEIVE			**RECEIVE**		
Received Power	**-69.26**	**dBW/m2**	Received Power	**-106.56**	**dBW/m2**
Received Power	**-109.17**	**dBW**	Received Power	**-145.25**	**dBW**
ACN Antenna Gain	3.00	dBi	Antenna Gain	38.00	dBi
ACN Noise Temperature	2304.00	K	Noise Temperature	331.00	K
ACN G/T	**-30.62**	**dB/K**	**Ground Station G/T**	**12.80**	**dB/K**
Noise Bandwidth	76.53	dB-Hz	Noise Bandwidth	76.53	dB-Hz
	45.00	**MHz**		**45.00**	**MHz**
Eb/No	**12.27**	**dB**	Eb/No	**19.61**	**dB**

2.6 Worst Case Scenario Assessment

The sustained operations scenario described in the Phase 0 Study is the most stressing. During sustained operations, ACNs continue to support Joint and Service component operations. Rapid maneuver on the ground and in the air is the essential doctrine of modern sustained combat operations. All the communications capabilities needed in early entry are also needed in sustained operations.

During deep interdiction and major offensive operations, the priority of support shifts to armored, mechanized, aviation, cavalry, and air forces that need to communicate on the move. Widely dispersed elements must communicate with higher, lower, supporting, supported, and adjacent units using existing CNR/SINCGARS, PLRS, EPLRS, Link 16, UHF/AM, VHF/AM, and MSE equipment. Deep offensive maneuvers by Army corps and divisions, deep air and aviation attacks, and armored cavalry regiment screening operations are particularly difficult to support with current communications capabilities.

These forces may maneuver so rapidly and deeply that conventional line of site communications cannot keep up. ACNs could provide uninterrupted battle command communications during rapid, deep maneuvers.

ACNs could also be used to link widely dispersed forces and to provide connectivity out-of-theater through satellite relay. By taking advantage of their stronger RF signal (relative to satellites), ACN relays could provide great improvement for on-the-move communications to support continuously moving tactical users. Over-the-horizon communications for forces on-the-move could be provided by BLOS relays of SINCGARS, UHF satellite retransmission (surrogate satellite), PLRS, EPLRS, and Link 16. Mobile users require no more than small, low profile, highly survivable Omni-directional antennas. Reachback communications with Handheld Radio Terminals (HHRTs) could also be required to link deep maneuver forces with higher headquarters and logistics control elements located in secure sanctuaries.

2.6.1 Connectivity Required for Sustained Operations Scenario

Figure 5 shows the connectivity needs during sustained operations identified in the Phase 0 Study. On the diagonal of Figure 5 are the number of channels of each radio type that must be provided. (Both receive and transmit functions are needed on the ACN for each channel.) Priority of service is also indicated following the "/", where 1 is highest priority and 5 is lowest. In general, the gateway function (i.e., interconnection of dissimilar radios) has lower priority than the relay function. In both the SINCGARS and UHF Radio case, multiple users share each channel as members of a net; in the HHRT case, one user utilizes one channel at a time, but many radios can share the channel sequentially, as in a telephone system. The HCTR MSE relay function is a MSE Node-Center to Node-Center trunking relay. In the cases of the Theater Broadcast transmitter and the Paging transmitter, the uplink signal to drive them can come from several places. They could arrive over the CDL uplink, or the Ku SATCOM receiver. The choice of which to use would be based on the particular tactical situation; flexible switching of this function is desired.

TO: / FROM:	JTIDS	EPLRS	PLRS	CNR	UHF Radio	HHRT	Ku SAT	UHF SAT	MSE Relay	CDL	PAGE Tx	BDCST Tx
JTIDS	1/2	G										
EPLRS	G	2/1	G									
PLRS		G	1/1									
CNR				20/1	G	G	G	G				
UHF Radio				G	20/1	G	G	G				
HHRT				G	G	200/1	G					
Ku SAT				G	G	G			1/5		1/4	1/2
UHF SAT				G	G							
MSE							1/5		2/2		1/4	
CDL											1/4	1/4

JTIDS/PLRS/EPLRS HIGH PRIORITY

VOICE & DATA HIGHEST PRIORITY

G = Gateway

Channels / Priority (1 to 5)

HHRT = Handheld Radio (Cellular-Like) (Voice & Data; One channel per 5 Radios)

CNR = Combat Net Radio

TWB = Tactical Wideband Relay

Figure 5 Connectivity Needs/Priorities for Sustained Operations

The ACN requirements for sustained operations (as described in the Phase 0 Study) are summarized in Table 8. Because the operational requirements can vary greatly, the actual maximum needs and the mix of required services will also vary. Therefore, it is important to have as much reconfiguration capability as possible.

Table 8 Communications Needs Summary for Sustained Operations

Function	Quantity	Use
Link 16	1	Air & Ground Situational Awareness
EPLRS	2	Position Reporting & Messaging
PLRS	1	Position Reporting
CNR	20 HDX	Combat Net Radios (voice & data)
UHF Radio	20 HDX	Net Radios, LPI, & Surrogate Satcom
Handheld Radio	200 chnls	Cellular-Like
Ku SAT	1	Out of Theater Connectivity from
UHF SAT	1	Out of Theater Connectivity from
MSE Relay	2	Wideband In-Theater Connectivity
CDL	1	Wideband Theater Link to / from ACN
Pager Tx	1	Theater Paging, Warning
Broadcast Tx	1	Augment GBS; for On-the-Move

HDX = Half-Duplex

3. SYSTEM DEFINITION

This section presents a system level introduction to a system infrastructure for the ACN that supports the technical concepts and goals described in the previous sections.

3.1 INTRODUCTION

A minimum set of functional goals is presented for the Airborne Communications Node (ACN) system framework. An architectural framework following the guidelines set forth in the Joint Technical Architecture (JTA), and the Programmable Modular Communications System (PMCS) is described.

The information contained in this document should be considered as expected and desired capabilities, services, interfaces, performance, and operation associated with the ACN. It is not intended to define or specify the ACN implementation.

The ACN should have an open, flexible, scaleable architecture to adapt to varying user communications requirements. The goals and objectives of an open, modular, flexible architecture include the following:

Programmability - The ability to implement varying capabilities by initializing different application software modules. As a result, common application software modules and common hardware modules replace the legacy hardware intensive designs of today. The use of common hardware and software configurations provides cost-effective solutions to implement dynamic user requirements.

Technology Insertion - The ability to add new technology without complete re-engineering and re-design. This supports ease of modification and upgrade.

Scalability - This relates to the ability to support the addition of quantitative growth within existing functions

Extendibility - This pertains to the ability to support qualitative growth for new functions.

The ACN architecture should be extendible to support growth and change in both technology and operational requirements.

Effective open system architectures will rely on physical modularity and functional partitioning of both hardware and software which should be aligned to facilitate the replacement of specific subsystems and components without impacting subsystems or components not replaced.

The subsystems and components described by the system design should be consistent with the system repairable level. In addition, application software should be modifiable without necessitating hardware changes.

Guidance is provided for developing an ACN system architecture through an ACN System Framework which, when supplemented with appropriate building codes in the form of open systems standards and the operational requirements, will establish an ACN system design.

3.1.1 Standards

As with the DoD's recent initiative to define the JTA, the standards selected for the ACN should meet all of the following criteria:

Interoperability and/or Business Case - Standards should ensure joint Service/Agency information exchange and support joint (and potentially combined) C4I operations. There should be a strong economic justification that the absence of a mandated standard will result in duplicative and increased life-cycle costs.

Maturity - The standards should be technically mature and stable. They should be widely accepted in multiple commercial markets.

Implementability - The standards should be technically implementable. This criterion could be measured by the standard's commercial availability.

Public - The standards are publicly available (e.g., open systems standards) or are held by trade associations, commercial forums, or consortiums.

Standards that are commercially supported in the marketplace with validated implementations available in multiple vendor mainstream commercial products take precedence. Publicly held standards are generally preferred. International, national, and industry standards are preferred over military or other government standards.

3.1.2 Open System Approach

An open system approach should be designed to facilitate the use of widely accepted standard products. Open specifications and standards used in the private sector can be used to leverage the benefits of the commercial marketplace and take advantage of the competitive pressures that motivate commercial companies to reduce prices and introduce new products developed with internal resources. Life-cycle costs can be reduced by a long-lived, standards based architecture that facilitates upgrades by incremental technology insertion, rather than by large scale system redesign.

3.2 PMCS System Framework Architecture

In seeking a cost-effective approach for the next generation communication system, the Office of the Secretary of Defense (OSD) has formed an Integrated Product Team (IPT) to explore the creation of an open systems architecture for the Programmable Modular Communications System (PMCS). PMCS-based products implement waveforms, encryption, and major communication processing functions in software.

Through modularity, PMCS-based products will use common open systems standards for hardware and software across a family of scaled and extended configurations for different platform environments. PMCS allows for future upgrades that provide cost reductions, performance enhancements, and technology insertion.

The IPT is currently developing a PMCS system framework with the following objectives:

1. Maximize use of available commercial/non-developmental hardware and software items to reduce recurring and non-recurring costs,
2. Minimize proprietary interfaces and maximize use of commercial standards to expand production sources, and
3. Minimize the number of unique hardware configurations and maximize software reprogrammability to increase the production base. This model forms a starting point for a PMCS system design.

The goals and objectives of the ACN are very similar to those of the PMCS task force. The ACN development effort should leverage from the work that the DoD PMCS completed.

The PMCS system guidance document provides insight into how to develop an open system architecture for a programmable, modular communications system. Where applicable, this guidance document should be applied to the ACN design.

3.3 ACN System Framework Architecture

This section presents an introduction to the ACN System Framework and its components.

***This framework is not intended to be a physical break down of the ACN system architecture*.**

The suggested system framework for the ACN is shown in Figure 6. The system framework allows for a common set of hardware and software modules that define a RF Front End unit, an Internetworking Switch Fabric, and a Communications Controller unit. In addition, there are existing platform assets that may be incorporated into the ACN infrastructure.

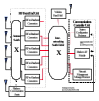


Figure 6 ACN System Framework

3.3.1 ACN System Framework Functional Modules

There are three primary units to the ACN system framework. These are:

〈 RF Front End
〈 Internetworking Switch Fabric
〈 Communications Controller.

In addition, existing platform assets may be incorporated into the overall system infrastructure.

Critical information flowing through the unit interfaces include data (Voice, Video, and Data), status, and control (communications configuration control, Global Hawk control, and network configuration).

3.3.1.1 RF Front End Unit

The ACN programmable RF Front End unit consists of the Antenna Switching Unit and RF-to-Baseband Conversion.

3.3.1.1.1 Antenna Switching

The ACN Antenna subsystems consist of RF switching, low noise amplifiers (LNAs) for receive and high power amplifiers for transmit. Figure 7 illustrates the antenna subsystem concept. Interference mitigation subsystems are also considered to be part of the antenna subsystems.

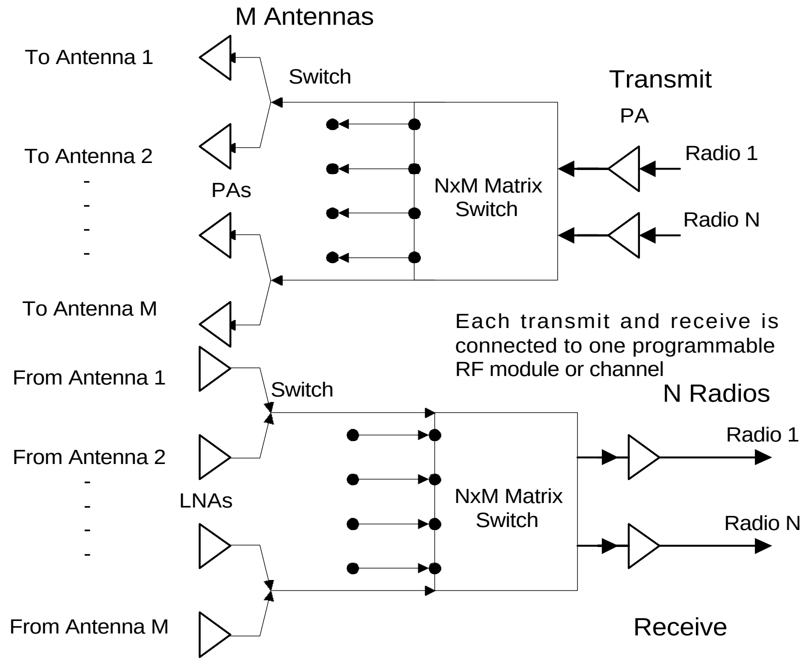


Figure 7 Sample Antenna Subsystem

Cosite interference is a serious problem when multiple ECCM or high power transmit antennas are located close enough to receive antennas to preclude high transmit to receive isolation. To meet performance goals, interference cancellation or interference mitigation systems are likely to be required. Therefore there will be a need for some type of antenna control.

3.3.1.1.2 RF-to-Baseband Conversion

The RF-to-Baseband Conversion module consists of the following functions:

- Antenna Interface
- RF-to-IF Conversion
- Modem (waveform generation, TRANSEC, modulation, demodulation, and error correction)
- Input and Output Function

〈 INFOSEC

Figure 8 illustrates a suggested functional division for the RF Front end.

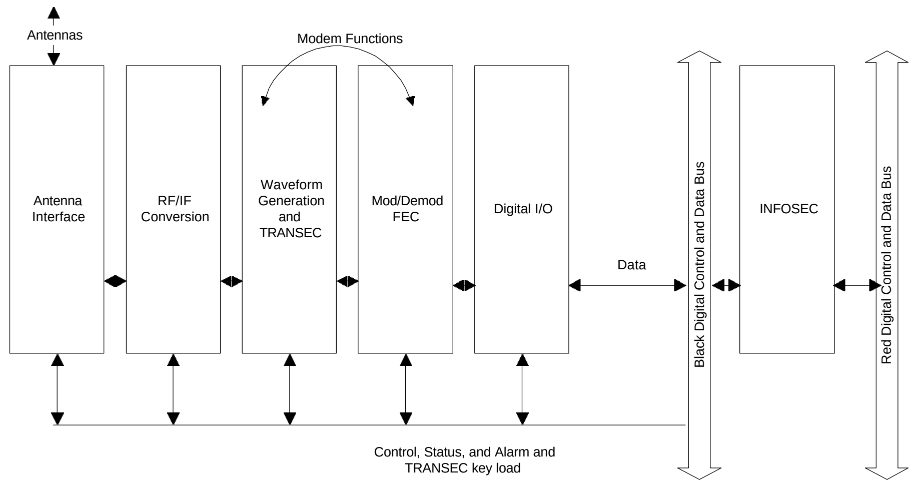


Figure 8 Suggested RF Front End Functional Division

The RF –to-Baseband Conversion Module provides the RF-to-baseband and baseband-to-RF conversion. It passes baseband data to/from the Internetworking Switch Fabric. It may also provide switching of RF and IF internal to the RF Front End.

3.3.1.1.2.1 INFOSEC Function

The Information Systems Security (INFOSEC) Functional Module provides the appropriate security measures to protect information being transmitted over an ACN from unauthorized personnel. These functions may be tailored for each ACN mission application, while providing for interoperability with other ACN or multiple ACN mission applications. This tailoring should be done based on the assets/information to be protected, the threat against those assets/information, and the applicable regulatory requirements.

The INFOSEC Functional module contains the following three primary sub-functions.

〈 Cryptography
〈 Key Management
〈 Security Monitoring and Control

The cryptography function provides message protection through communications security (COMSEC) techniques and provides waveform protection through transmission security (TRANSEC) techniques. These cryptographic functions are executed on a special purpose, dedicated processor.

Key management includes all activities related to cryptographic keys; key loading, over-the-air-rekey, over-the-air distribution, key selection, zeroization, etc.

Security monitoring and control serves as the "INFOSEC Conscience" of the ACN, performing auditing of critical actions, supporting access control, providing "black side" control, etc.

3.3.1.1.2.2 Internetworking I/O Function

The RF-to-Baseband Conversion Module requires connectivity with the Internetworking Switching Fabric. The Internetworking I/O functional module provides the interface between the INFOSEC module (RF module if security is not an issue) and the Internetworking Switching Fabric. Any and all internetworking critical system interconnects should be selected from the JTA. The protocols, mechanical/electrical interfaces and standards should JTA compliant.

3.3.1.1.3 Radio Capabilities

The RF Front End should support the RF channels listed in Table 9 while maintaining existing/modified platform communications services (i.e., CDL, Ku-band SATCOM, TBS feeder link, etc.). Additional communications links to support the Warfighter Internet are TBD.

Table 9 Expected RF Channel Capabilities

Service	Frequency (MHz)	Power (Watts)	Number of Antennas
VHF	30-88 MHz	20-30	5 with 4 channels/antenna
AM Rx AM/ATC FM/Maritime	108-118 118-156 156-174		2
UHF	225-400	20-30	5 with 4 channels/antenna
EPLRS/PLRS	225-400	20-30	1
Handheld	800-900/1800-1900/2400-2500	?	?
MSE Extension	1350-1700	20	2
Link 16	960-1215	20	1
TBS	1350-1700	20	1

3.3.1.2 Internetworking Switch Fabric

The Internetworking Switch Fabric is a non-blocking deterministic backbone that provides the necessary system throughput and quality of service (QOS) for moving baseband data to/from the Communications Controller as well as between other communications assets. The Internetworking Switching will serve as an efficient, high speed, transport mechanism providing the interconnection of all ACN communications capabilities. Any JTA recommended switching network standard will be considered. It must be flexible, scaleable, and non-blocking; and support a wide range of data types and rates.

3.3.1.2.1 Performance of the Internetworking Switching Fabric

The throughput of the ACN multimedia (data, voice, video) switching backbone should support all full duplex channels from the RF Front Ends. With the worst case scenario as an example design, the data throughput would need to support 32 RF front end channels with data rates from 600 bps to 1.54 Mbps and wideband data rates of 30 Mbps.

The Internetworking Switching Fabric has interfaces with the Communication Controller unit and the INFOSEC functional module within the RF Front End unit as well as the Handheld unit.

3.3.1.3 Communications Controller Unit

The Communications Controller Unit consists of three functional modules: System Configuration Processor, Network Management and Message Processor, and Platform Interface. They perform the following tasks:

> The System Configuration Processor is responsible for the storage of the ACN mission requirements and configuration data, and the configuration and control of the ACN payload.
>
> The Network Management and Message Processor is responsible for moving the text messages to the correct RF-to-Baseband Conversion Module for redistribution. It will also act as a reformatting device (if required) to support interoperability between dissimilar radios. This module could also support routing and network management functions in a multiple ACN UAV scenario and could include Warfighters Internet specific functions.
>
> The Platform Interface Module provides all necessary interfaces and conversions to support interoperability between the existing/modified platform communications services and the ACN payload. The existing/modified communications services include command and control channels, Wideband LOS links (e.g., CDL), and Ku-band SATCOM.

3.3.1.3.1 System Configuration Processor

The System Configuration Processor manages the ACN communication payload configurations by providing the necessary programming and data to the RF Front End and associated modules. The System Configuration Processor also has access, over the Internetworking Switching Fabric, to the other modules that make up the ACN Communications Controller.

The processor controls the resources needed to execute the following:

- Loading new software
- Start-up/shut-down
- Built in Test
- Instantiation of a virtual radio (RF to I/O), re-instantiation
- Changing virtual radio parameters
- Changing to a different virtual radio
- Monitoring status during normal operation

The System Configuration Processor receives user parameters/information and system commands through the platform command and control channels or the RF network. The processor works in conjunction with the INFOSEC module and should provide the appropriate security access procedures for using and modifying system configuration and application software. The configuration data also includes cryptographic keys and equipment.

Other functions potentially controlled by the System Configuration Processor include:

- Over-The-Air reconfiguration
- Frequency allocation and registration
- Assessment of Frequency and/or channel availability and use
- Quality of service issues

To accomplish the above functions the processor should provide for:

<u>Database Management</u>: Provide for storing, updating, and sharing system information needed for ACN operations. The management function must support built-in operating and information integrity and ensure that data is valid for all tasks executed in the system.

<u>RF Front End Configuration</u>: Provide for configuring the RF Front End via simple commands. This may require that the individual modules have intelligence to process the System Configuration commands.

<u>Built-In-Test (BIT)</u>: Provide commands to modules to perform BIT, collect responses, and report the BIT information to the ACN MCE. BIT functions may be performed on demand or at regular intervals in the background of other ACN functions.

<u>Operations Execution</u>: Manage the resources required for proper execution of the ACN mission operations. Once operations are established, the processor queries the RF Front End modules and reports their system performance. Included are data for measuring Quality of Service statistics, bit error rates, signal-to-noise ratio, fading characteristics, and the interference environment.

ACN MCE Interface: The processor provides complete access to all of its capabilities through the ACN MCE interface module. Information sent to the MCE includes, but is not limited to, status, warning messages, and system interrupts.

Internetworking Interface: This provides access to the system's preset capabilities. The processor also monitors the Internetworking module to provide the MCE module with warning or system interrupt messages when changes are made to the system configuration.

The platform command and control subsystem consists of the existing platform command and control processors. These subsystems make up the functionality required to fly, sustain, and retrieve the Global Hawk UAV. They also include the communication and crytographic assets required to communicate with the UAV.

3.3.1.3.2 Network Management and Message Processor

The Network Management and Message Processor provides a variety of services. These services include; data routing, bridging, dissimilar radio message reformatting, and switching in the ACN.

Potential functions provided by the Network Management and Message Processor include:

〈 Routing/Switching associated with transporting formatted data (e.g. an IP router or ATM switch)
〈 Bridging or providing a gateway capability to tie together dissimilar channels.
〈 Message/Link Processing associated with the network aspects of specific legacy waveforms.
〈 Multimedia Processing that includes the handling of the different protocols and algorithms for moving digitized voice, graphics, and video.
〈 Resource Management of external resources that are connected in a networked configuration.

3.3.1.3.3 Platform Interface Module

The Platform Interface Module provides all necessary interfaces and conversions to support interoperability between the existing/modified platform communications services and the ACN payload. This includes both command and control interfaces and data interfaces. Platform data links will interface to the Internetworking Switch Fabric. The ACN command and configuration data (from the MCE command link) should be forwarded to the System Configuration Processor and/or Integrated Flight Management System (see below).

3.3.1.4 Existing Global Hawk RF Subsystems

Current Global Hawk communications assets support the functions and communication channels necessary to; (1) fly the aircraft, (2) monitor and control the airborne payload, (3) transport data from the sensor payload to the ground. The aircraft communication systems include both air-to-ground communications and air-to-satellite communications. These systems are described in the Global Hawk Specification and System Description Document for the Common Data Link and contain the following:

- UHF/VHF Transmit and Receive;
- Ku-band Satellite Communications (SATCOM); and
- Line-of-Sight X and Ku-band Communications.

Since the sensor payload function will not be implemented in the ACN the possibility exists that these communication assets and command and control systems can serve dual duty in support of both platform/payload command & control and ACN communications. This equipment is already accounted for in the size, weight, and power budget and should not be budgeted against the size, weight, and power stated as part of the caveats listed in Section 1.2. A brief description of these assets is provided below.

The design goal is to achieve the most cost-effective ACN RF Infrastructure. There is no requirement to keep the existing communications suite of equipment. However, there is a requirement to maintain the existing aircraft RF control channels. The Global Hawk communications have been implemented and should be employed unless a cost, size, weight, or power advantage is available in an alternative implementation.

3.3.1.4.1 UHF/VHF Transmit and Receive

The UHF/VHF transmit and receive system provides the following three functions:

- Air Traffic Control (ATC) which is an audio UHF channel connected to a UHF antenna;
- Primary UHF channel connected to a UHF SATCOM antenna; and
- Redundant UHF/VHF channel connected to a UHF/VHF antenna.

The UHF/VHF transceivers are 13 lb., 5.0" x 5.6" x9.8" boxes powered by the aircraft's 28 VDC supply. The transceivers require 500 W power when transmitting. The primary and redundant modules have a high powered amplifier (HPA) and low noise amplifier (LNA)/diplexer. The HPAs weigh 14 lb., is 5 x 7 x 10 inches, and requires 28 VDC and 200 W. The LNA/diplexers weighs 2 lb., is 5.4 x 1.2 x 6 inches and requires 28 VDC and 7 W.

3.3.1.4.2 Ku-band SATCOM

The SATCOM system consists of a SATCOM Radio Frequency Amplifier (RFA) with upconverter, a HPA and associated High Voltage Power Supply (HVPS), and a 48" SATCOM antenna. The RFA is a 26 lb., 10.4 x 11.9 x 16.2 inch unit using 28 VDC at 56 W and 115 VAC at 22 W. The HVPS is a 63 lb., 10.5 x 14.2 x 18.7 inch unit using 28

VDC at 50 W and 115 VAC at 1700 W. The HPA is a 56 lb., 10.4 x 9.3 x 22.5 inch unit using 28 VDC at 33 W. The HPA transmits up to 400 W. The 48” antenna is a 46 lb., 48.8 x 48.8 x 54.6 inch unit using 28 VDC at 35 W.

3.3.1.4.3 Line-of-Sight (LOS) Communications

The LOS modules are the LOS RFA with upconverter and 70 W traveling wave tube amplifier (TWTA) and 9” LOS antenna. The RFA is a 35 lb., 14 x 5.2 x 21.2 inch unit using 28 VDC at 82 W and 115 VAC at 413 W. The LOS antenna is a 9 lb., 10.2 x 10.2 x 14.6 inch unit using 26 VAC at 7 W.

3.3.1.5 Global Hawk Mission Control

The Global Hawk Mission Control consists of the existing Integrated Flight Management Computer (IFMC) on-board and the Mission Control Element (MCE) on the ground. The System Configuration Processor manages the ACN payload configuration and control. However, it may be feasible to incorporate some or all of this functionality into the existing IFMC.

3.3.1.5.1 Integrated Flight Management Computer (IFMC)

The IFMC is a VME based computer that uses an AMD29050 RISC processor. The Global Hawk contains two redundant IFMCs. The most critical IFMC functions are:

- Built In Test (BIT)
- UAV Navigation
- Communication System Control
- Sensor Management Unit Control
- Data Link Control
- Ground Test.

The ACN is expected to retain the current IFMC architecture and all of the critical IFMC functions except for the Sensor Management Unit Control.

3.3.1.5.2 Mission Control Element (MCE)

The MCE is contained in an 8’x8’x20’ shelter and consists of the following major components:

- A SGI Challenge XL computer
- Four SGI Indigo2 workstations
- A Tactical Database
- An Advanced Synthetic Aperture Radar System (ASARS) processor

- A 450 GB 24 hour image store system
- An FDDI based Image LAN
- An FDDI based Data LAN
- Miscellaneous communication equipment

The most critical MCE functions are Mission Planning and Image Processing. One MCE workstation is devoted to mission planning and two are devoted to Image Processing. The fourth workstation is used for Command and Control. All four workstations are tied to the Challenge XL computer via the Data LAN.

The Challenge XL computer is a VME based super computer that can contain up to 25 VME boards. As configured for the baseline Global Hawk system, it can perform at a peak rate of 960 MIPS. The Challenge XL handles most of the Image Processing tasks and all of the communication tasks. Approximately, 26% of the Challenge XL's software is devoted to image processing tasks and the remainder is devoted to mission planning and communications.

The ACN is expected to retain the current MCE architecture and all of the major MCE components except the ASARS processor, the 24 hour image store, the Image LAN and possibly one of the two SGI workstations devoted to image processing.

4. DESIGN EXAMPLE

One possible design developed from the ACN system framework is described below. The design focuses on current open systems technology. **This design is an example only**. Figure 9 shows the block diagram for the example design. The shaded areas in the figure denote modules not included in the Communications Controller, Programmable infrastructure, or internetworking switching fabric.

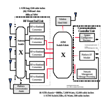


Figure 9 Design Example

4.1 Open System Standards and Interfaces

Identifying critical interfaces is a first step in moving from a system framework to a system design. The interfaces are described below:

4.1.1 Internetworking Switch Fabric

The ATM/SONET fiber optic backbone was chosen for the Internetworking Switch Fabric because it provides for quality of service for voice, data, and video, has market acceptance and continued growth, availability of products both hardware and software.

4.1.2 RF-to-Baseband Conversion Module

The VMEbus IEEE1014 and ANSI/VITA-1 were chosen for the RF-to-Baseband Module backplane. They provide a well-defined electrical and mechanical standard interface and have the following attributes:

- A large quantity of products are available commercially
- There are many different types of Processor, I/O, and Analog technology available
- There has been continuous performance growth since 1980 from 40 Mbps to 320 Mbps

The VMEbus also fits nicely into a standard ARINC-604 ATR chassis. This chassis is defined by the 1ATR, 3/4 ATR, and 1/2 ATR standards.

4.1.3 Communication Controller Unit

The VMEbus was also chosen for each of the two processors and interface module defined for the Communications Controller. The VMEbus backplane provides the same advantages for the communication controller as for the RF Front End. The processors and interface module can be included in one chassis that can be connected to the Internetworking Switching Fabric.

4.2 RF Front End Unit

A single RF-to-Baseband Conversion module should support two full duplex RF channels. This will require six VMEbus cards. The VMEbus cards size and weight are estimated to be 6Ux160mm, approximately 6” x 9”, and 2.0 lbs each respectively. The average RF-to-Baseband Conversion module will draw 70 Watts. Sixteen ATR chassis will be required to support 32 RF full duplex channels. The initial data throughput of the RF Front End Unit is estimated at 155 Mbps (ATM OC3 rate) and should be scaleable to 622 Mbps (ATM OC12 rate).

The Antenna Switching Subsystem is estimated to need only 1 6U VME card and draw negligible power. However, the RF power amplifiers required to support this configuration will require another 1Kw of power.

4.3 Internetworking Switch Fabric

The Internetworking Switch Fabric design is based on an ATM switch that supports a minimum of 2.4 Gbps throughput. Each connection to this switch consists of an OC-3 fiber optic link to allow the Communications Controller and the RF front end a non-blocking network for transferring digital data, commands, status, and control information.

Currently, only commercial switches are available and do not meet the ACN environmental requirements. However, the Marine AAA(V) and Air Force U2 platforms are considering ruggedized ATM switches to meet their platform needs. These switches are estimated to weight 5.0 lb., require 50 Watts power, and fit in a 10 inch by 14 inch chassis and they should be suitable for use in the ACN.

One concern yet to be explored is the number of I/O circuits supported by the ATM switch versus the number of I/O circuits needed in such a switch, for each platform.

4.4 Communication Controller

The Communication Controller processors are embedded in a single standard 1ATR chassis with 16 VMEbus slots. Any 64 bit processor could support the processor requirements for the communication controller processors with clock speeds at or above 100 MHz (e.g., Pentium Pro, Power PC 603,604, Alpha, PA-RISC, SPARC or UltraSPARC). The memory required is 32 Mbytes or greater.

4.5 System Operating System and Software API

The ACN may require multiple software operating systems. However, the RF Front End will require a real-time deterministic operating system like VxWorks from WindRiver, HPRT from Hewlett Packard or Lynx OS from Lynx real-time systems. The Communication Controller would possibly need a DII COE compliant operating system like WindowsNT or SUN Solaris.

Message passing between the RF Front End and the Communication Controller requires meeting the real-time deterministic requirements of the ACN platform. Message passing protocols should comply with JTA identified building blocks. Within the RF Front End, a deterministic throughput is required but the Communications Controller may use a sockets based solution. TCP/IP should be adequate for the routing and data passing over the Internetworking Switching Fabric and offers the best protection from hardware and operating system differences.

4.6 Security for the Design Example

For ease of design, focus is placed on the physical breakdown of the hardware and software modules of the ACN framework. However, security plays an important role in the choice of technology required to meet mission requirements.

The design example assumes that all security keys are stored in FLASH memory and are called by a trusted operating system based in the communication system configuration controller. Keys will be loaded prior to the mission take off. The cryptographic equipment is assumed to be in software algorithms or modules (NSA Modules 98 program) and totally interoperable with legacy waveforms and system configurations. The design also treats the ACN platform as a system high device.

This ACN design will operate in a “system high” mode. It is assumed that simultaneous, multiple levels of security will be supported by employing multiple levels of encryption at the user level.

4.7 Limits of Current Technology

Assuming that the RF Front end is housed in a 1ATR chassis with 16 VMEbus boards, eight chassis are needed to support 31 RF channels. The Communication Controller requires 1ATR chassis to house the communication configuration system controller and The Network Management And Message Processor. The total number of 1ATR chassis required is ten without including the Antenna switching, HPAs, LNAs, or cabling assemblies.

This results in an estimated size, weight, and power requirement of at least 15,600 cubic inches, 825 lbs, and 7100 watts.

The example ACN design appears to meet the given size constraints. However, the design exceeds the specified power, and cooling limits, and probably the weight constraints also (i.e., 6000 W power and

4500 Watts of cooling, 900 lbs). To overcome these potential problems, a “real life” design will have to incorporate and/or develop more advanced technologies than were assumed in the sample design.

5. Risk Mitigation

The DARPA ACN program is a technology demonstration effort. Some of the proposed capabilities will likely be provided by new, state-of-the-art technologies. New, unproven technologies introduce an inherent risk factor. It is imperative that risk mitigation planning be included as an integral part of any proposal.

Risk management should be an integral part of any ACN program. The ACN risk management process should include the following steps:

- Risk Identification - determining what the risk areas are;
- Risk Assessment - quantifying and ranking the risk levels;
- Risk Mitigation Plans - determining what steps should be taken to reduce the risks to acceptable levels for each program stage; and
- Risk Management - integrating these steps and providing the monitoring and execution of the plans to reduce risk.

This should be an iterative approach to achieve the following objectives:

- Achieve pre-planned levels of risk reduction at each program milestone;
- Periodically reassess program risk to ensure the mitigation of any new risk issues;
- Ensure the allocation or program assets for the priority risk issues;
- Enable the execution of expeditious recovery plans.

APPENDIX A Acronym List

ABIT	Airborne Information Transmission System
ACN	Airborne Communication Node
A/D	Analog to Digital
AM	Amplitude Modulation
ANSI	American National Standards Institute
ARITA	Airborne Reconnaissance Information Architecture
ATA	Army Technical Architecture
ATC	Air Traffic Control
ATM	Asynchronous Transfer Mode
ATR	Austin Trumble Radio
BIT	Built-In-Test
BITS	Battlefield Transmission System
BLOS	Beyond Line-of-Sight
BMDO	Ballistic Missile Defense Office
C4I	Command, Control, Communication, Computer, and Intelligence
CC	Communications Controller
CDL	Common Data Link
CNR	Combat Net Radio
CSE	
CODEC	Coder-Decoder
D/A	Digital to Analog
DO	Data Output
COTS	Commercial Off-the-Shelf
DAMA	Demand Assigned Multiple Access
DARO	Defense Airborne Reconnaissance Office
DARPA	Defense Advanced Research Projects Agency
DASA	Demand Assigned Single Access
dB	Decibel
DISA	Defense Information Systems Agency
DoD	Department of Defense
ECCM	Electronic Counter-Countermeasures
EFC	Executive Function Command
EIRP	Effective Isotropic Radiated Power
EMI	Electromagnetic Interference
EPLRS	Enhance Position Location Reporting System
FAA	Federal Aviation Administration
FAAD	Forward Area Air Defense
FDX	Full Duplex
FOW	Forward Orderwire
GBS	Global Broadcast System
GHz	Giga-Hertz
HAE	High Altitude Endurance
HCI	Human Computer Interface

HCTR	High Capacity Trunk Radio
HDX	Half Duplex
HH	Handheld
HHRT	Handheld Radio Terminal
HMI	Human Machine Interface
HPA	High Powered Amplifier
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IF	Intermediate Frequency
INFOSEC	Information Systems Security
I/O	Input/Output
IP	**INTERNET PROTOCOL**
IPT	Integrated Product Team
IR	Infra-Red
ISR	Intelligence, Surveillance and Reconnaissance
ISSP	Information Systems Security Policy
JCIT	Joint Combat Intelligence Terminal
JTA	Joint Technical Architecture
JTIDS	Joint Tactical Information Distribution System
kbps	Kilo-Bits-per-second
kHz	Kilo-Hertz
LAN	Local Area Network
LNA	Low Noise Amplifier
LOS	Line-of-Sight
LRE	Launch Recovery Element
MCE	Monitor and Control Element
Mbps	Mega-bit-per-second
MHz	Mega-Hertz
MSE	Mobile Subscriber Equipment
NCS	Network Control Station
NRL	Naval Research Laboratory
NSA	National Security Agency
ODISC4	Office of Director of Information Systems for C4
OOTW	Operations Other Than War
OS-JTF	Open Systems Joint Task Force
PBX	Private Branch Exchange
PLRS	Position Location Reporting System
PMCS	Programmable Modular Communications System
PMEC	Primary Mission Equipment Commands
RF	Radio Frequency
Rx	Receive
SADL	Situation Awareness Data Link
SAR	Synthetic Aperture RADAR
SATCOM	Satellite Communications

SINCGARS	Single Channel Ground and Air Radio System
SHF	Super High Frequency
SNCS	Surrogate Network Control Station
SNR	Signal to Noise Ratio
SONET	Synchronous Optical Network
SOS	Speed of Service
TACSAT	Tactical Satellite
TBD	To Be Determined
TBS	Tactical Broadcast Service
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
THAAD	Theater Area Air Defense
TOD	Time of Day
TRANSEC	Transmission Security
TS/SCI	Top Secret/Sensitive Compartmented Information
TWB	Theater Wideband
TWITA	Traveling Wave Tube Amplifier
Tx	Transmit
UAV	Unmanned Aerial Vehicle
UCM	User Command Message
UHF	Ultra High Frequency
UFO	UHF Follow-on
VDC	Volts Direct Current
VHF	Very High Frequency
VITA	VME International Trade Association
VMF	Variable Message Format
WI	Warfighter Internet